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ANALSYSIS OF ASAR AND PALSAR DATA FOR OPTIMISING FOREST COVER MAPPING – A GSE FOREST MONITORING STUDY

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ABSTRACT

For the Russian Service Case of GSE FM ENVISAT ASAR APP data (HH/HV, swath 7) were used during the first two years. For optimal SAR based forest cover mapping a well suited SAR data set is required. Thus emphasis is put on the analysis of ASAR time series throughout the seasons. The investigation comprises for each image of the time series the analysis of the signatures of the relevant land cover classes and their separability. For forthcoming GSE FM service production PALSAR L-band data will be introduced. L-band data can be assumed to complement the data input and afford an improved forest cover mapping whilst the costly manual classification refinement effort is minimised. Various PALSAR products will be analysed regarding their suitability for forest map production. Regarding the separability of forest and non-forest, different PALSAR acquisition modes as well as winter coherence images have been investigated.

Keywords: SAR, ASAR, PALSAR, GSE-FM, forest cover mapping, forest cover change mapping

1 INTRODUCTION

Russia holds the largest forestry resources in the world with about 22% of the world's forest. One of the most wooded regions of Russia is the Irkutsk Oblast compromising about 10% of Russian forested territory. The detection and monitoring of forest management activities and disturbances in this district is of great interest for the State Forest Service. Large changes in forest management due to legal and illegal logging as well as natural disturbances such as forest fires, insect outbreaks or wind damage are very common. Those short termed changes can not be captured by the State Forest Service, which collects forest information for inventories periodically every 10-15 years. Spaceborne Earth Observation techniques are suited to overcome these restrictions. SAR data have been chosen because of the awkward illumination conditions and the high frequency of cloud coverage.

1.1 GSE FOREST MONITORING – INTENSION AND ACCOMPLISHMENT

GSE FM is one element of the GMES (Global Monitoring for Environmental and Security) initiative of the ESA Earthwatch Programmes. Main goal is to deliver customised and policy-relevant information mainly based on EO data in ready-to-use packages in the field of Climate Change, Sustainable Forest Management as well as in Environmental Issues and Natural Protection. The supplied products and services are validated and standardised to support decision-making and improved policies that enable cost effective sustainable forest management in various countries. To guarantee the GSE FM standards all products including their specifications and instructions for production are collected within the Service Portfolio Specifications.

1.2 THE RUSSIAN SERVICE CASE

The Service Case relates to the Irkutsk Oblast (Fig. 1). It is based on agreement with the Forest Agency of Irkutsk General Survey of Natural Resources (FAI of GSNR). The GSE FM service case in Russia has a large influence on effective forest monitoring and inventory at regional scale.

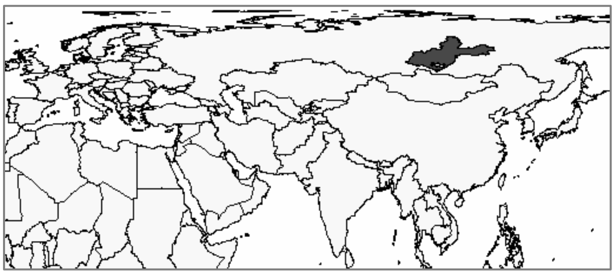

Figure 1. Russian Service Case Site Irkutsk Oblast.

Recent information on forest extent and changes therein are currently generated using ENVISAT ASAR APP IS7 (HV/HH) data because of their availability and qualification. The provided products of this service case include a forest area map, a clear-cut/burned area map and a forest area change map. The forest area map is derived from recently acquired ASAR data. For the generation of the other maps archived LANDSAT TM data around year 1990 are utilised. All products will be implemented into the forest inventory of the FAI of GSNR and are produced within three years for regions of rapid change in the Irkutsk Oblast, comprising a total area of 200,000 km² (see Fig. 2).

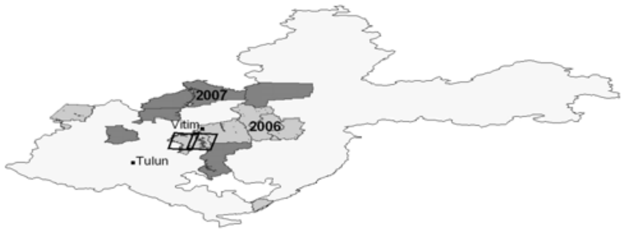

Figure 2. Mapping areas within Irkutsk Oblast, frames: location of ASAR time series, dots: climate stations.

1.3 SITE CHARACTERISTICS

The Oblast is located in central Siberia (52°-64° N, 96°-118° E) and comprises 739,000 km². The Middle Siberian Plateau in the southern part of the territory is characterised by hills up to 1,700 m. The northern part is plain with heights up to 500 m. Taiga forests (birch, aspen, pine, larch etc.) dominate and cover ca. 82% of the region. The Irkutsk Oblast exhibits continental climatic conditions. The yearly amount of precipitation is generally below 450 mm; the winters are very cold and dry, the summers are warm and feature the precipitation season. Drastic short term temperature variations are common. Key climatic parameters are depicted in Fig. 3 for the station Tulun (year 2006). Tulun is indicative for the western Irkutsk Oblast.

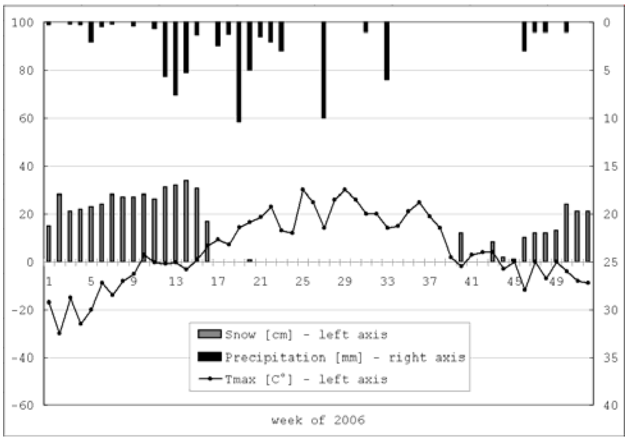

Figure 3. Climatic data Tulun station (2006): weekly averages for Tmax and snow, weekly sum for precipitation.

1.4 DATA PROCESSING AND MAPPING

The SAR data methodology chain comprises preprocessing (calibration, orthorectification, topographic normalisation [Zyl et al., 1993; Stussi et al., 1995], and ratio computation), classification, post-classification refinement, manual separation of clear-cuts and burned areas with the forest area map as origin and change map production. Data analysis and classification are based on image objects (segments), where segments are identified using a multiresolution segmentation algorithm (Baatz & Schäpe, 2000; Benz et al., 2004). Manual post-classification refinement is necessary to fulfil the requested mapping accuracy. The quality assessment of the GSE FM products is performed by the Service Provider (SP) and by the End User.

2 ANALYSIS OF ASAR TIME SERIES

2.1 ASAR DATA SET

The time series comprises two scenes with bordering tracks and the same frame as depicted in Fig. 4. The time series consists of six acquisition dates for each scene as summarised in Tab. 1.

Table 1. ASAR time series: acquisition dates per scene

	West (T376)	East (T104)
February	-	14.02.2006
March	05.03.2006	21.03.2006
April	-	25.04.2006
May	14.05.2006	-
June	18.06.2006	-
July	23.07.2006	04.07.2006
August	27.08.2006	-
September	-	12.09.2006
October	-	-
November	05.11.2006	21.11.2006

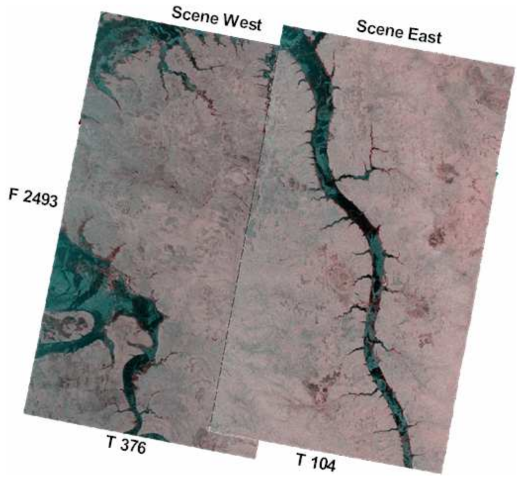

Figure 4. ASAR time series: two scenes, six acquisition dates each, March data depicted (RGB = HH-HV-HV).

2.2 PRESUMPTIONS

This study is strongly application oriented. It aims at answering the pragmatic question: What is the best acquisition period for intensity based forest/non-forest discrimination? By a number of L-band studies (e.g. Leckie & Ranson, 1998; Rauste, 2005, Santoro et al., 2006) it was proved that summer data are superior to winter data. However, using C-band clear-cut vegetation and remaining trees at fire scars could cause (too) high backscatter whereby the discrimination from forest would be hindered. There is a number of in places opposing factors and processes (clear cut, fire scar, and forest conditions; soil moisture and surface roughness; crown freezing; precipitation, snow layer etc.) which need to be considered to answer the above stated question.

2.3 DATA ANALYSIS AND DISCUSSION

A preliminary visual appraisal initiated the analysis of the time series, neither summer nor winter data appeared to be best suited. The highest contrast was evident at the April-scene. A signature analysis was conducted for substantiating this observation. For taking the variability of forested and non-forested areas into account, the forest classes "(prevailing) needle leafed", "(prevailing) broad leafed", and "young forest" (age about 10 years) have been considered. Non-forest was separated into "clear-cut" and "burnt". Additionally the classes "water", and "settlement" have been introduced. For each of these classes about 15 sample areas have been generated per scene. Each sample area was considered being an image object, thus the average backscattering coefficient per sample area was used as input for further statistical investigations. Fig. 5 depicts the mean backscattering coefficient for each acquisition date separated by landcover class and polarisation for the eastern scene. Strong temporal backscatter variation is apparent for all classes. The high backscatter of "water" during the winter months is due to freezing. The forest classes exhibit their backscatter maximum during the growing season, although this trend is more distinct for the "broad leafed", and "young forest". Due to canopy freezing the backscatter decreases during winter. The non-forest classes "clear-cut" and "burnt" exhibit similar temporal backscatter variation. High backscatter is apparent during the growing season; low backscatter appears in winter and spring. The absolute minimum emerges in late April. The temporal dynamic range between minimum and maximum backscatter is 4 dB/5 dB (HH/HV). Regarding to the temporal dynamic range of the backscattering intensity the forest and non-forest classes feature a comparable behaviour. Additionally, the backscattering intensities do not differ very much at each acquisition date (0-2 dB). The only exception is the April acquisition (4 dB/5 dB for HH/HV). Unfortunately there was no acquisition for the western scene in the April cycle.

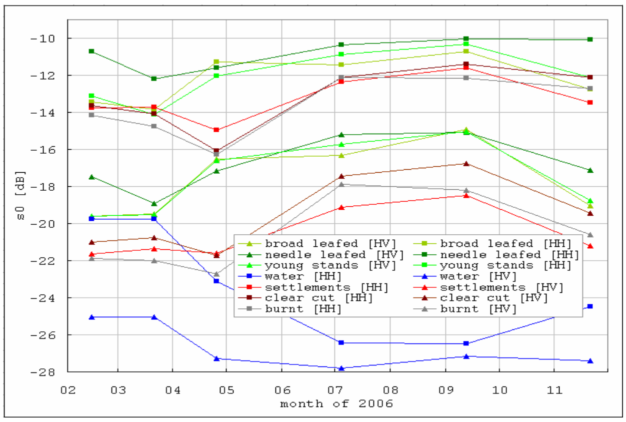

Figure 5. Temporal variation of backscatter separated by landcover class and polarisation, eastern scene.

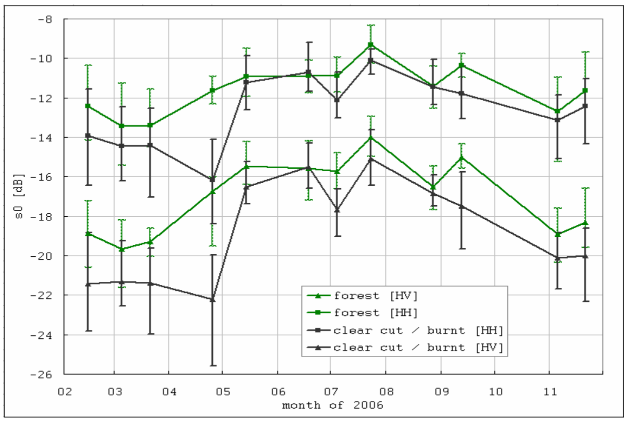

Figure 6. Temporal variation of backscatter for forest and non-forest separated by polarisation, both scenes. Error bars flag min and max respectively.

Fig. 6 outlines the temporal variations of backscatter for the two key classes. The "forest" class was generated by merging the signatures of the three above stated forest classes; "non-forest" contains the merged signatures of "burnt" and "clear-cut". To ensure an impartial analysis of the acquisition date driven separability of forest and non-forest a separability measure was calculated. The normalised Jefferies-Matusita distance was selected for this task (1.0 = signatures separable; 0.0 = signatures inseparable). The separability analysis was performed on pixel level. The signature for each class was derived basing on the above described samples. Performing on pixel level was necessary to derive a useful gradation of the separability for the various acquisition dates. Tab. 2 outlines the separability of forest and non-forest for both scenes. Generally the separability analysis reflects the results of the signature analysis. Intra-seasonal separability variations (especially at growing season) exceed a general separability difference between summer and winter. This certainly refers to short term variations such as precipitation effects (Mätzler, 1987). Those variations are smaller in winter. Also the separability seems to be slightly higher (Leckie & Ranson, 1998; Mätzler, 1987). Hence, for ASAR APP based forest/non-forest discrimination winter data could be preferred against summer data. However, there is still the out-performing separability of 25th April. Moreover, high separability of forest/non-forest at late April / early May is also evident for 17 additional scenes, were no complete time series was on hand.

Table 2. Separability of forest/non-forest, both scenes

	burnt/clear-cut vs. forest		burnt/clear-cut vs. forest
14.02.2006	0.38	04.07.2006	0.36
05.03.2006	0.49	23.07.2006	0.24
21.03.2006	0.34	27.08.2006	0.11
25.04.2006	0.78	12.09.2006	0.46
14.05.2006	0.23	05.11.2006	0.38
18.06.2006	0.11	21.11.2006	0.27

The 25th April scene (plus the 17 other scenes) fall within the thawing period. During that period the snow is wet. This is especially true if it is raining on the snow layer, as occurred in April 2006. The trees canopy at this time is generally free of snow, not frozen and partly developed. The ground vegetation at the non-forest areas is barely developed. The snow layer at non-forested areas is wet and more or less even. Incoming radar waves are reflected specular or are absorbed. During the growing season the ground vegetation and the high surface roughness at the non-forest areas hinders their separation from forest. During winter the trees canopy is frozen and produces less backscatter, the forest/non-forest contrast is reduced. Additionally at the non-forest areas some backscatter is generated via SAR wave-ground interaction (interpenetration of very dry snow) or scattering within the snow layer (Leckie & Ranson, 1998; Way, 1990).

3 ANALYSIS OF PALSAR DATA

At phase 3 of GSE FM PALSAR data will be added to Service Production. This new data input is assumed to reduce the manual classification refinement afford, as lower radar frequencies are of particular adequacy for forestry applications. In this section the suitability of PALSAR data for GSE service production is assessed. The data set comprises FBS (fine beam, single polarisation) HH and PLR (polarimetric) summer and winter intensities as well as winter coherence data (see Tab. 3). Most of the scenes are not superimposed. Fig 7 gives an example for each of the data products (ca. 30 km² each).

Table 3. Data and separability burnt/clear-cut vs. forest

date	mode	position	separability: pixel/object	
19MAY06	FBS	54°12'N 99°94'E	0.97	1.00
19MAY06	FBS	55°59'N 99°58'E	0.99	1.00
19MAY06	FBS	56°08'N 99°46'E	0.99	1.00
14AUG06	FBS	54°12'N 101°56'E	0.99	1.00
14AUG06	FBS	54°61'N 101°44'E	0.93	1.00
27DEC06	FBS	56°84'N 104°16'E	0.94	1.00
27DEC06	FBS	57°33'N 103°99'E	0.93	1.00
13JAN07	FBS	56°83'N 103°62'E	0.97	1.00
13JAN07	FBS	56°83'N 103°62'E	0.94	1.00
11FEB07	FBS	56°84'N 104°18'E	0.95	1.00
11FEB07	FBS	57°33'N 104°02'E	0.93	1.00
28FEB07	FBS	56°84'N 103°64'E	0.96	1.00
28AUG06	PLR	56°93'N 99°96'E	0.50 (HH) 0.88 (HV) 0.53 (VV)	1.00 (HH) 1.00 (HV) 1.00 (VV)
28AUG06	PLR	57°42'N 99°78'E	0.51 (HH) 0.93 (HV) 0.43 (VV)	1.00 (HH) 1.00 (HV) 1.00 (VV)
14SEP06	PLR	56°44'N 99°63'E	0.64 (HH) 0.85 (HV) 0.59 (VV)	0.86 (HH) 1.00 (HV) 0.82 (VV)
14SEP06	PLR	54°12'N 101°56'E	0.75 (HH) 0.94 (HV) 0.75 (VV)	1.00 (HH) 1.00 (HV) 1.00 (VV)
13OCT06	PLR	57°41'N 99°75'E	0.65 (HH) 0.99 (HV) 0.39 (VV)	1.00 (HH) 1.00 (HV) 1.00 (VV)
17MAR07	PLR	56°45'N 99°67'E	0.31 (HH) 0.74 (HV) 0.32 (VV)	0.92 (HH) 1.00 (HV) 0.92 (VV)
17MAR07	PLR	57°42'N 99°25'E	0.27 (HH) 0.71 (HV) 0.24 (VV)	0.83 (HH) 1.00 (HV) 0.81 (VV)
27DEC06 11FEB07	FBS Coh.	56°84'N 104°16'E	0.99	1.00
27DEC06 11FEB07	FBS Coh.	57°33'N 103°99'E	0.99	1.00
13JAN07 28FEB07	FBS Coh.	56°84'N 103°62'E	0.98	1.00
13JAN07 28FEB07	FBS Coh.	57°33'N 103°45'E	0.98	1.00
01JAN07 16FEB07	FBS Coh.	56°35'N 102°69'E	0.98	1.00
01JAN07 16FEB07	FBS Coh.	56°84'N 102°54'E	0.99	1.00

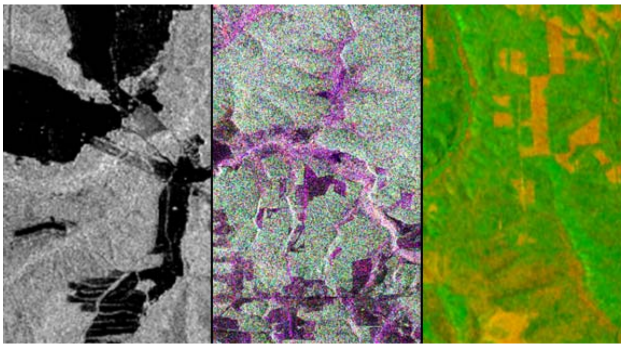

Figure 7. PALSAR data samples. L: FBS HH Int., M: PLR (RGB= HH/HV/VV), R: (RGB= Coh/Int/Ratio Int.)

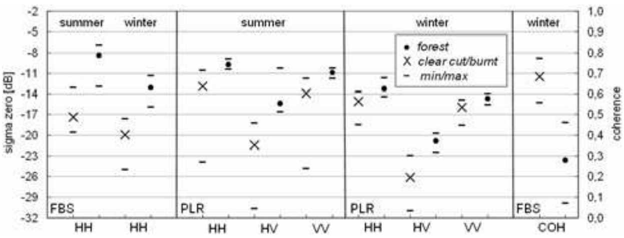

Figure 8. Object based signatures: forest, burnt/clear-cut

For assessing the suitability of PALSAR data class signatures and class separability have been computed as above. This step was conducted for each scene separately. Fig. 8 summarises the class signatures for forest and burnt/clear-cut separated by data product and season (signatures averaged for various scenes). As expected forest produces much higher backscatter compared to clear cut/burnt areas. On the other hand, non forest areas are much more stable (especially during winter) and thus exhibit clearly higher coherence measures. As there is hardly any overlap between the signatures high separability can be assumed for most of the scenes. This can be confirmed by the normalised Jefferies-Matusita distance values given in Tab. 3. Mostly the maximum is reached for the object based calculation (last column) and high values are achieved on pixel basis. Summer data seems slightly better suited than winter data, which is concordant with the literature. The relatively poor separability basing on PLR data is owing to the higher noise and speckle effect and to the reduced resolution. This drawback is negligible when working with image objects. However, convenient image segmentation can be hindered.

4 CONCLUSIONS

The Siberian boreal region is characterised by continental climate comprising long and cold winters with considerable accumulation of snow. The thawing process typically initiates suddenly and takes 1-4 weeks. If C-band intensity based forest/non-forest discrimination in boreal regions is aspired the thawing season might be the best choice for acquisition. Shorter temporal sensor baselines would ensure to meet the aspired acquisition time frame. The initiation date of thawing is subject to regional and temporal variations, thus weather and snow conditions must be checked before acquisition.

This initial PALSAR data analysis proves the high potential of L-band for forestry applications. Especially the usage of winter coherence with summer intensity (cross-polarisation in particular) will allow precise forest cover mapping. The combination of PALSAR and ASAR could even extend the Service Portfolio of GSE FM.

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